Theoretical Framework of Building Lighting Intensity Control by Using IoT

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***Abstract*—Recently, computational simulation is implemented effectively throughout building design, development and operation stages. The motivation of this concept is based on the flexibility provided by the computational simulation activity itself. Where it does not involve any additional cost to generate various unassociated design for building and it services the concept virtually. Existing building however involved with the entire life operation which is required for continuous monitoring in term of performance. Correspondingly, the need for appropriate platform that contribute to building sustainability lead to the employment of Internet of thing (IoT). IoT in general refer to system that integrates a network, intelligent processing devices, machine and digital devices subsequently enable in having an interaction with human. Most of the cases will involve one-way data transfer over a network to processing device and require person-in-charge to monitor devices interaction. Synchronization between the cloud that stored the data fed from the sensing device and application that serve as the platform for visual representation are strictly vital concern. This paper aims to present a theoretical model that work as monitoring platform for light intensity level based on IoT technology. In relation, by supplying a real time data of light intensity levels on any room of interest, at the same time taking into consideration in term of convenient platform employment for building information modeling. Even though, this case study is mainly designed and tested on academic building, its application is precisely wide in general. For instance, when the lighting system becomes a major issue, such as operating theater in hospital, greenhouse plantation, photographic studio and many more. With that in mind, the platform is not only to fulfill the visual comfort of the building occupant but the retrieved information enable the development of baseline for future reference and troubleshooting purposes.**

Keywords—building information modeling, internet of thing, light intensity, monitoring

I. INTRODUCTION

In general, Internet of Things (IoT) referred to global networking and connectivity of devices, users and information so that they are readable, traceable and controllable on the internet [2]. Wide implementation of IoT in the present can be seen in numerous field such as medical healthcare assistance, industrial automation, traffic management, agriculture management, smart cities and many more [5][6]. As a matter of facts, IoT implication in society aims towards providing better and reliable quality of operation and services in urbanization world by having everyday devices connected in network. Though, vulnerability in term of security enhancement for IoT database management will be major concerned.

Conventionally, IoT implementation in buildings are not just focusing on monitoring and controlling rather taking into consideration the aspect of maintaining utility, comfort and energy savings for more convenient indoor environment. It is corresponding to the active progression of Building Automation System (BAS) technology that currently implied. Where, automation of building system involved centralizing building services controls and monitoring [4]. On top of that, enabling bi-directional and symmetric machine-to-machine (M2M) access and communication with virtually numerous number of public IP addresses provided by IPv6 which is latest communication protocol [3]. These make it convenient to connect any network of devices in physical world to the internet for monitoring and controlling remotely at any time via the internet. As the physical parameters being transmitted and act as unique input to optimize the services with the act of sensing, processing and actuation utility, human is still remain essential integral parts of respective IoT system [7].

In the context of this research, IoT involved in integrating group of sensors (photosensitive light module) and microcontroller which able to communicate by sending and receiving feedback for the purpose of monitoring and controlling of building services that responsible for lighting

system. With that in mind, this paper intentionally reviewing common platform for real-time monitoring and subsequently proposing the theoretical model that conveniently perform as monitoring and controlling platform for light intensity level based on IoT technology.

II. INTERNET OF THINGS FOR BUILDING MONITORING PLATFORM

Technically, the Internet of Things is the result of integrating sensing, processing, networking and automation technology in the series of communication activity that capable of narrowing the gap between physical world and virtual digital world. With great capabilities however there are some technical concerns regarding the implementation IoT as building monitoring platform. For example, scalability and interoperability of communication and service discovery between different elements subjected in IoT environment to achieved efficient operation [8]. In addition, abundant amount of data collected by the sensing devices require for organize and centralize storage where it can be manage and stored in secured. This lead to the issues of data privacy and security, in which the accessibility of the data should be restricted to authorized personnel by having layered confidential authentication. Therefore, in the following section the discussion will focus the features involve in developing IoT based real time monitoring platform and the challenges that might prevail.

A. Common Platform for Real Time Monitoring

Currently, IES<VE> had introduced their new cloud service namely IES ERGON for real-time storage and providing real-time data feed for building virtual simulation. The synchronization between IES<VE> software and their cloud service enable precise retrieval and management of real-time building profile rendering down to 1 minute time steps [9]. In addition, it contributed to enhancement of building model calibration besides typical use of benchmark data from daily measurement. As for the accessibility of the cloud for synchronization, both project URL and project token will be compels to proceed with simulation processing and rendering. The common workflow for IES<VE> and their cloud service light intensity level monitoring are showns in Figure 1.

Referring to Figure 1, it is noticed that the process only involve monitoring process without the presence of active automation activity. This is because this platform only designed to interrogate the real-time data retrieved from the cloud to continuously calibrate the simulation to represent the actual building condition. While IES<VE> is not an open source platform, they proved to be very convenient to perform plenty of building simulation having fed with relevant data that influence both indoor and outdoor environment [10].

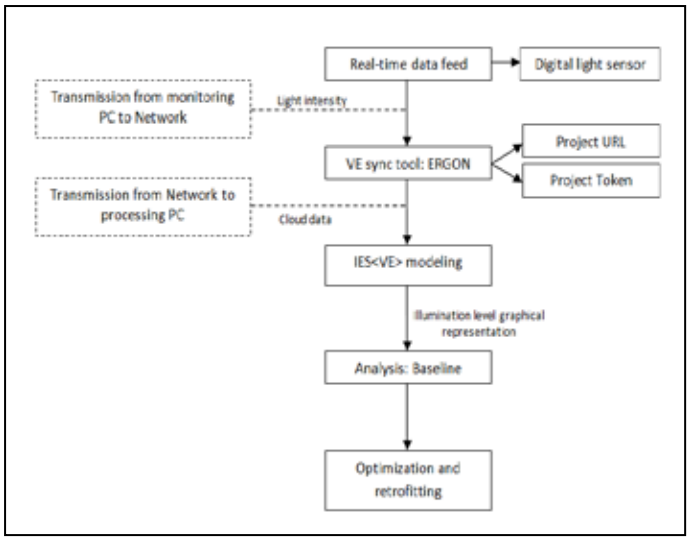

Fig. 1. IES-Ergon real time monitoring platform and common workflow. [9]

III. FRAMEWORK FOR DATA ACQUISITION AND CONTROLLED VIA INTERNET OF THINGS

Interoperability between two processes which is monitoring and controlling of light intensity parameters will be discussed in this section. The need for remote monitoring has been highlighted in previous section, while having the ability to remotely control building light intensity level is another possibility to be explored. Integration of sensor and microcontroller along with relay component proved to work as monitoring and controlling devices with pre-defined input requirement for the environment [1].

Communication between electronic devices is a vital subject to be considered. Since, it is the ultimate aim for this IoT platform to have structured machine-to-machine (M2M) networks [16]. In which, it is a reliable way to control and manage the data transfer and data availability via the internet among network of devices to be dynamically reconfigured for optimum resource utilization [15]. To summarize, the concept of M2M in IoT platform is where the corresponding hardware within the platform can be located and remotely configured to make use of data and update their state. In relation, there are several types of communications between integrated circuits such as serial peripheral interfaces (SPI), inter-integrated circuit (I2C) and universal asynchronous receiver/transmitter (UART) driven communication. Communications protocols in integrated circuit may cover from authentication, synchronization to signaling. As for communication between Arduino to other Arduino as will be proposed in this case study, it involved serial communication. I2C communication protocol was implied so that the task able to be distributed among the arduino that acts as master device (perform monitoring) and arduino that acts as slave device (perform controlling).

In this section, the theoretical framework IoT platform for monitoring and controlling light intensity level will be proposed and discussed in much detail.

A. *Proposed theoretical framework for IoT monitoring and controlling platform*

Figure 2 show the theoretical framework for IoT-based monitoring and controlling platform for light intensity level. It involved two microcontroller circuits to perform the task assigned in this study. Compatibility and ability to interact among hardware are thoroughly considered to avoid any failure of hardware since it involved electromagnetic relay controlling much higher voltage circuits. At the monitoring phase circuit, the Arduino are assigned to be the master device. Which, in this case the master played a role of receiving the information of light intensity level from the photosensitive light module. The input from the sensor is then process by the intermediate software, Parallax data Acquisition tool (PLX-DAQ) and was send to the server. Any authorize client PC will be able to retrieved the live data feed. On the other hand, at the controlling phase another Arduino was employed. This Arduino represent as a slave device that received the input from master Arduino and process the data logic for decision making either to close or break the relay circuit. Pre-set value as a reference parameter for the Arduino to make a logic decision should earlier insert in a line of program code.

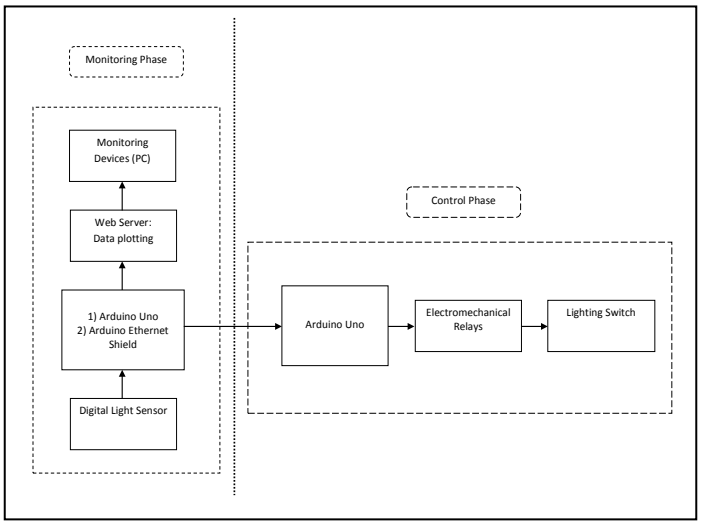

Fig. 2. Theoretical framework IoT platform for monitoring and controlling light intensity level

1) Sensing component

For the purpose of this case study the sensing component consists of photosensitive light module, Arduino Uno board and Arduino ethernet shield. Each component play vital role either it is from monitoring or controlling platform. Basically, integration of both monitoring and controlling platform with employment of two microcontroller lead to this IoT based platform.

a) Photosensitive light module

This photosensitive light module provides resistance reading in the range of 0 to 1024 based on resistance reaction to luminance level. Eventually, the resistance reading was converted to lux unit using the equation 1 to 4, [18] which was inserted into Arduino's sketch.

$$\text{lux} = 500/R_{ldr}\ (\text{kOhm}) \quad (1)$$

$$R_{ldr} = (10000*(5 - \text{Vout}))/\ \text{Vout}) \quad (2)$$

$$V_{out} = \text{Analogreading} * 0.0048828125 \quad (4)$$

$$\text{lux} = (2500/V_{out}-500)/10 \quad (3)$$

Communication between the photosensitive module and microcontroller (Arduino) was assigned on analog pin (A0) via serial communication.

b) Arduino board : Arduino UNO ATmega328P as master and slave microcontroller

Arduino is an open source, mini computing platform that capable of sending and receiving information over the internet. As a microcontroller board-based it works by taking inputs and controlling the outputs through series of communication with other electronics devices [14]. Arduino integrated development environment (IDE) is where the program code are developed where the interactive software give feedback on written code and debug process can be executed. Though it requires PLX-DAQ to act as an software add-on for the master Arduino to logging the data into Microsoft Excel. Data received from parallax microcontrollers will be drop into column thus allowed convenient analysis of real-time sensors data monitoring platform. In addition, PLX-DAQ was able to provide up to 26 real-time data reading and with their respective graph plotting. As for communication between master Arduino to slave Arduino there are many option in allowing both to communicate. One of the options is through standard serial communication perform connecting jumper wire at both RX and TX pin of both Arduino. Another option is through A4 and A5 pin which is known as I2C serial communication. The connection between the two Arduino not just involve receiving input from the master, they also sharing power supply as shows in Figure 3.

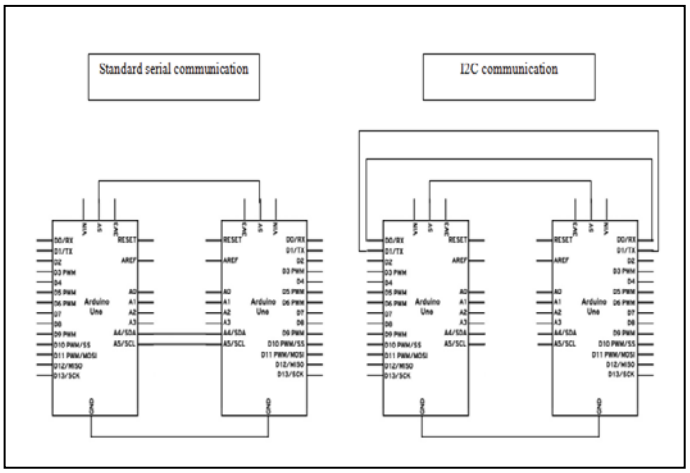

Fig. 4. serial communication for master and slave arduino

c) Arduino ethernet shield

With the installation of Ethernet shield on Arduino board it enables processing device to answer a HTTP request. Prior to Ethernet shield's IP address navigating at the browser, the Arduino will respond with HTML for a browser to display the input values from all six analog pins. The Ethernet controller

of the Ethernet shield are meant to be connected to the Arduino boards via the SPI bus.

d) Arduino sketch Algorithm

Two set of Arduino's sketch was designed to carry out two separate tasks which is (1) monitoring and publish sensor input to web server (Master) and (2) controlling based on pre-defined threshold (Slave). Sets of algorithms describe the sketch for master and slave Arduino was like the following:

Algorithm #1 (master)

1) Include library for communication and Ethernet module
2) Define input pin for sensor
3) Define mac address and ip address of Ethernet module
4) Start I2C wired communication define as master
5) Reading the input from sensor and store it.
6) Send sensor input to slave Arduino
7) Define delay
8) If Arduino board was connected send the sensor input to web server in the form of table/graph (database)
9) Print input
10) Stop send input to server when board was disconnected

Algorithm #2 (Slave)

1) Include library for communication
2) Define input pin for relay
3) Reading the input from master
5) Define output
6) Define function that will trigger relay when received input
7) Read and process received event from I2C
8) Decide relay event low/high
9) Return

2) Webserver: data log and database management

Ever since the platform suggest IoT platform of real-time monitoring, thus the application-layer protocol that governs message-passing between clients-side and servers-side environment are essential to log a data and develop interactive web-based database management [11]. The application is known as web server, which imply server-side task of Hypertext Transfer Protocol (HTTP) to fulfilled client request by running a scripting language to generate and render dynamic Hypertext Markup Language (HTML) pages.

a) Server-side environment development

Abundant open access server-side scripting which come in handy to provide customize interactive, convenient web server depend on specific requirements and secured data stores. PHP, java and python is among popular server-side language that allowed convenient integration with Structured Query Language (SQL) which is the language for creating database [12]. In general, the algorithm for web server consist of (1) request message, that specify a request method and Universal Resource Identifier (URI) for requested resource (2) response messages, that include a status line and resource representation [11][13]. Both request and response message includes a start line, message headers with optional message body and message trailers to be interpreted by client browser.

b) Database management with MySQL

The aim for the web server in this IoT platform to acquire real-time data logging and data plotting on a web page accessible to authorize personnel. Thus, MySQL software platform will be definitely appropriate open source database platform to be explored because they offered data manipulation language features for query data. While offering compatibility for windows operating system, latest application plugin offered by MySQL to enable oriented data analyst is MySQL for Microsoft Excel. This plug-in on the other hand, is very feasible since it provide another alternative for data logging from arduino to Excel as discuss in earlier section.

3) Slave Arduino to relay

The main reason of another Arduino need to present is that Arduino Uno by itself does not multi-task well. Since it is only consist of single processor which so far in our concern can efficiently execute a single line of code at a time. To multi-task an Arduino is not much reliable it is because set of code that work well by itself may not work well when combine with other set of code to be in the same program. Relay was also known as electrical switch. Though there is multi-function relay known as microcontroller relay which has real time data monitoring, detection of abnormal condition, fast processing speed [17]. The Arduino can be programmed to turn on the relay when a certain event occurs. This means that pre-set value as mentioned earlier will provide triggered event for the relay whether the relay is normally open (NO) or normally close (NC) relay switch.

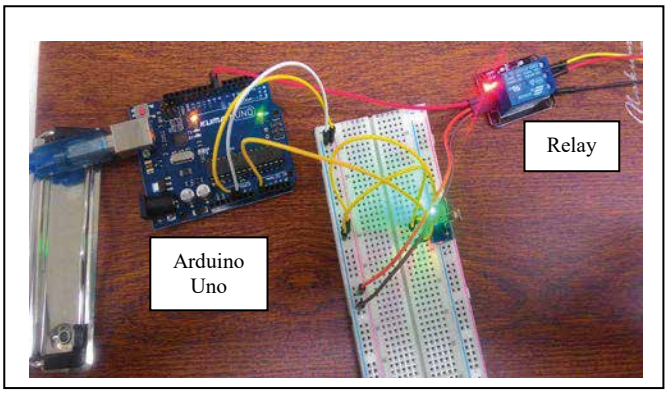

Fig. 5. Standard serial communication between relay and slave arduino

For example, the event when the light intensity reached higher than the range of <300-450> lux the relay will operate. The trigger can also be at a set of time intervals. Though some concern regarding the electromagnet of the relay that directly powered from the Arduino Uno Board, which having the possibility for damaged microcontroller if something goes wrong with the relay.

IV. Conclusion

In general, proposed IoT platform integrating two microcontroller functions to perform two line of program which is for monitoring and controlling. Even though IoT platform vulnerable to the risk such as data security and organizing server management it is still worth to imply and optimized. Having internet connectivity to access facility condition anywhere around the globe is very convenient not just for facility manager instead it opened the opportunity for wide scope of building control. Information such as facility operation and condition able to be up-to-date visualized and interpreted. With about anything can be connected and communicate either there are part of analog or digital world. Physical world are better reflected with possibilities generation of IoT platform that enable data exchange between set of microcontroller and appropriate human interface data management with web server. Though the proposed framework is for small scale project however, for bigger scale project instead of Arduino Uno, Arduino Mega can be employed.

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